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## (54) Image processing

(57) The more modern imaging systems employ solid state detector area arrays which "stare" at the viewed scene (and are thus known as "staring arrays"). Unfortunately, these arrays are not very uniform, and the sensitivity and the output absolute value of the detector elements can vary significantly over the array. A normalisation process can be employed, but if such a process is based on the assumption that each element's output is a linear function of its input there may be problems. The present invention suggests a solution to this difficulty; it proposes dividing the operating range of the elements into a plurality of adjacent regions, calculating the gain and offset correction factors for each region separately (upon the basis that the input/output relationship in that region is linear), and then in operation correcting the element's output in accordance to which region it is in.

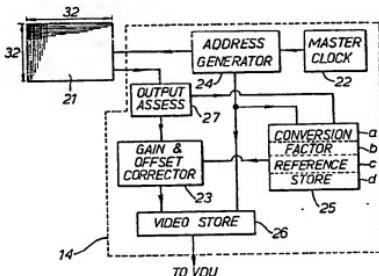
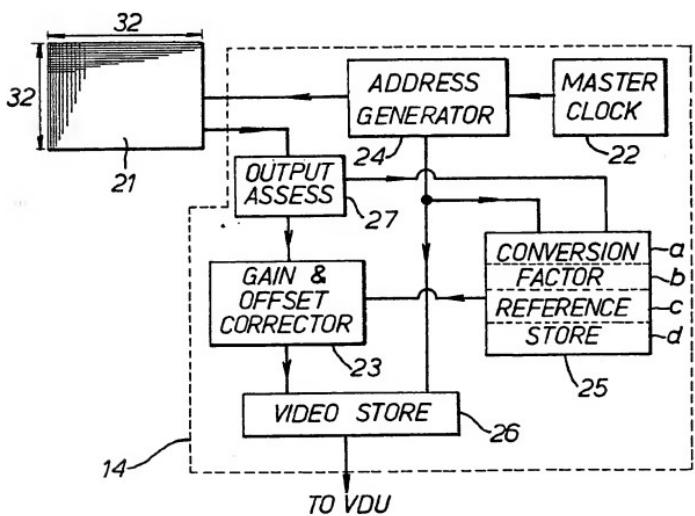
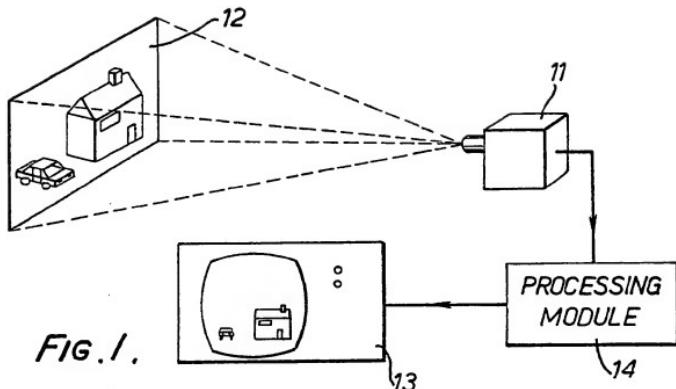


FIG. 3.

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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.  
This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

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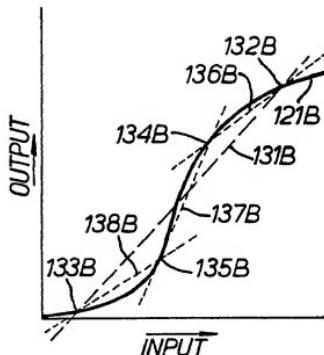
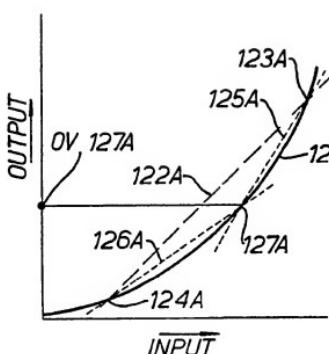
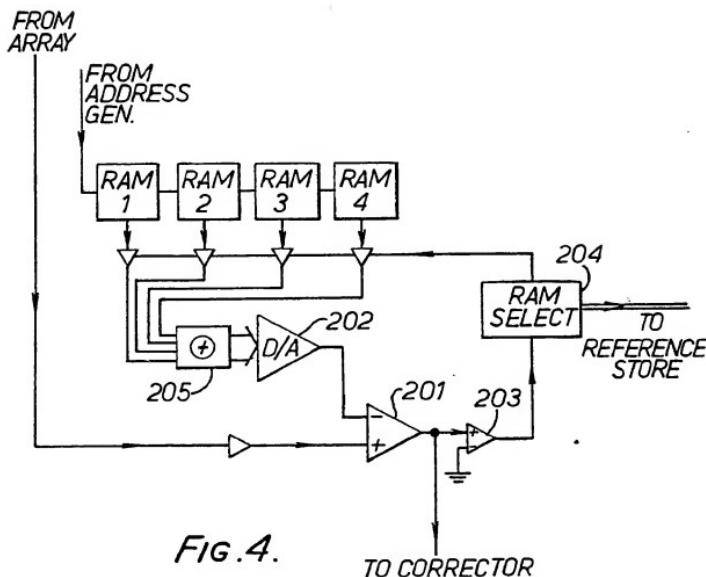


FIG. 2A.

FIG. 2B.



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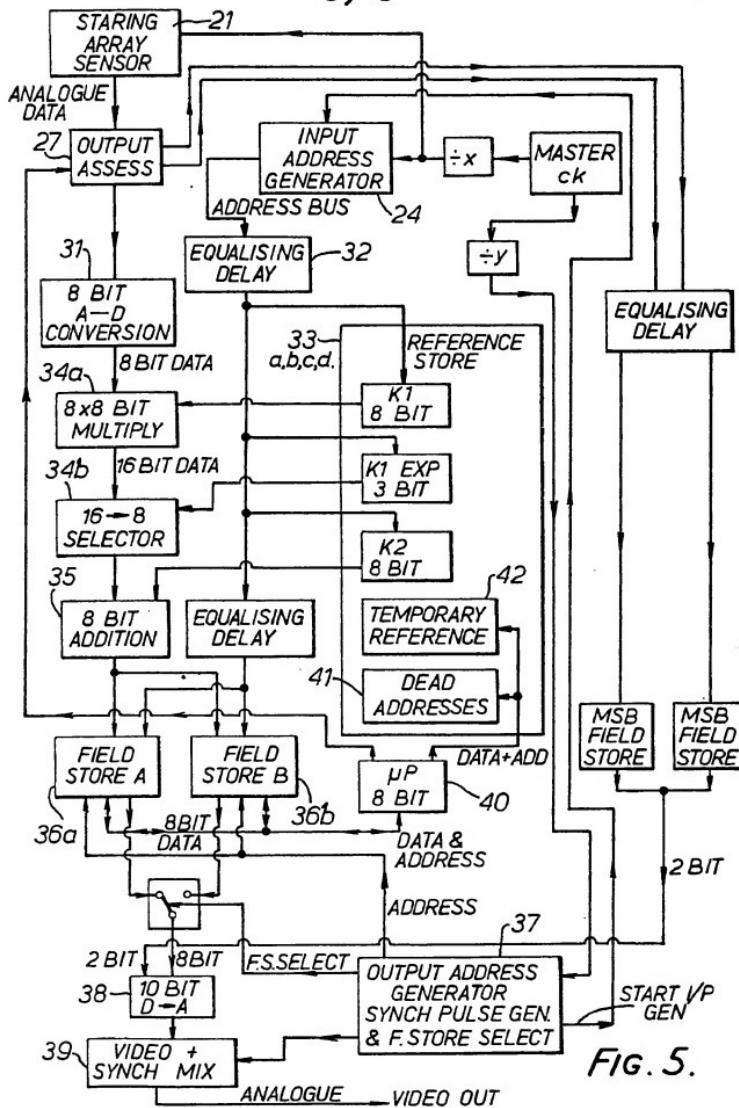


FIG. 5.

## SPECIFICATION

## Image processing

- 5 This invention concerns image processing, and relates in particular to the processing of image data derived from a detector array, especially an infra-red detector array.
- In a number of fields it is now common to supplement, or even to replace, imaging systems using visible light with corresponding systems using infra-red (IR) radiation (and referred to as thermal imaging systems). Many techniques are employed in the detection of this IR energy; one uses a single detector cell (commonly 10 a cryogenically-cooled mercury cadmium telluride device) across which a system of rotating mirrors scans the image of the viewed scene in successively vertically displaced lines, while another uses a line of such individual detector cells across which the image is scanned as a single swathe. Detector systems of this type are, however, delicate, and expensive to construct and maintain at peak efficiency, and the more modern IR 15 imaging systems employ solid state detector area arrays which "stare" at the viewed scene (and are thus known as "staring arrays"). These arrays are analogous to those used in present-day television cameras except that they are smaller (as few as 32 elements square as opposed to one or two thousand square) and are constructed so as to be IR sensitive rather than visible light sensitive.
- Unfortunately, the current level of technology is not capable of constructing IR sensitive detector arrays with any real consistency and uniformity (and indeed has some trouble with visible light arrays). As a result, 20 the sensitivity (the gain in output for a specified gain in input) and the output absolute value (dependent upon both the gain and the output at some specified input level, which latter is referred to as the "offset") of the detector elements can vary very significantly over the array. Indeed, the variation is usually markedly larger than the output changes caused by the differences in radiation output of the viewed scene; this means that the raw output from the detector array is practically useless, and must first be processed in some way to 25 provide - ultimately - a meaningful picture.
- The problem may in the long term be solved by improvements in the technology enabling detector arrays - especially IR arrays - to be constructed so that all the elements in the array have the same gain and offset. For the present, however, the invention of our copending Application for UK Letters Patent No. 8329470 (I6768/ELL) puts forward quite a different solution, in which the output of each individual detector element is 30 normalised (corrected to the value that an average element would give). Specifically, there are found for each detector element the values defining its gain and offset, there are then recorded for each element the two factors that will normalise these values (convert each to the mean value of the entire array), and thereafter the relevant two normalisation factors are in use applied to the output of each element, before that output is employed to form the desired image of the viewed scene, so that the output is modified to the value 35 it would have if it had emanated from an element having the predetermined average values for gain and offset.
- In the method of the invention of the aforementioned Application No. 8329470 the output of each detector element is normalised before it is used to generate the desired image. By the word "normalised" is meant that the output value is changed to the value that would represent the output of an average detector element 40 under the same input conditions (and "average" means a detector element whose input/output characteristics are average when compared with those of all the elements in the array that actually work). Though there may be other ways of defining the more important operating characteristics of a detector element, it seems presently acceptable to refer solely to the gain and the offset of each element. As mentioned hereinbefore, the gain of an element is the arithmetical factor connecting change in input to 45 change in output, while the offset is the arithmetical factor defining (with the gain) the absolute output for a specified (but arbitrary) input. At a first approximation it is satisfactory to say that a detector element's output is throughout its range a linear function of its input. If this is indeed satisfactory, then the element's output may be described by the equation

$$Y = AT - B$$

50

(where Y is the output, T is the input - and represents the temperature of the viewed scene - and A and B are constants). A plot of Y for a range of values of T gives a straight line of slope A intersecting the "Y" axis (when T = 0) at B. The constant A is thus the gain of the element (a change in T causes A times that change in 55 Y), while the constant B is the offset (the convenient point is with zero input - T=0 - when the element still gives an output B).

The average gain  $\bar{A}$  and average offset  $\bar{B}$  for a series of n elements are

$$\bar{A} = \frac{A_1 + A_2 + \dots + A_i + \dots + A_{n-1} + A_n}{n} = \overline{\sum_{i=1}^n A_i}$$

5

$$\overline{B} = \frac{B_1 + B_2 + \dots + B_i + \dots + B_{n-1} + B_n}{n} = \frac{\sum_{i=1}^n B_i}{n}$$

and the mean output value  $Y^*$  is thus

10

$$Y^* = \overline{A} \cdot T + \overline{B}$$

(1) 10

For any particular element (the  $i$ th one) :

15

so

$$Y_i = A_i \cdot T + B_i$$

$$\frac{T = Y_i - B_i}{A_i}$$

Combining (1) and (2) :

20

$$Y^* = \overline{A} \cdot \frac{(Y_i - B_i)}{A_i} + \overline{B}$$

25

$$= \overline{A} \cdot Y_i + (\overline{B} - \overline{A} \cdot \overline{B})$$

or

$$= K1_i \cdot Y_i + K2_i$$

(3)

30 where

$$K1_i = \overline{A} \text{ and } K2_i = \overline{B} - \overline{A} \cdot \overline{B}$$

$K1_i$  and  $K2_i$  are the gain and offset correction factors that are used to convert the output  $Y_i$  of any particular element. That output can be normalised - brought to the value that the average element would have given - by applying the two correction factors  $K1_i$  and  $K2_i$ , special to that particular element as in (3) above. Thus:

$$Y'_i = K1_i \cdot Y_i + K2_i$$

where  $Y'_i$  is the desired normalised value of  $Y_i$ .

40 In order to use this gain/offset normalisation technique it is necessary first to know the two correction factors  $K1_i$  and  $K2_i$  for each element. These may be calculated from a knowledge of the gain and offset  $A_i$  and  $B_i$  for each element - and these may in turn be calculated (assuming each element has a linear response) from a knowledge of the outputs of all the array elements at each of two input levels. In operation the procedure might be as follows:-

- 45 1) The array is pointed at a scene of uniform high temperature, and the output of each element noted.  
 2) The array is pointed at a scene of uniform low temperature, and the output of each element noted.  
 3) For each element the two outputs are then used to calculate the gain  $A_i$  and the offset  $B_i$  by solving the simultaneous equations

50

$$Y_{i1} = A_i T_1 + B_i$$

$$Y_{i2} = A_i T_2 + B_i$$

- 4) Thereafter there is calculated the average gain  $\overline{A}$  and offset  $\overline{B}$  for all the elements in the array.  
 5) Finally, there is calculated - and stored, ready for use - the two correction factors  $K1_i$  and  $K2_i$  applicable to each element.

All this is based on the assumption that each element's output is a linear function of its input. Unfortunately, however, this may not always be so - and specifically the relationship may vary sufficiently from a linear one that the gain and offset correction factors  $K1_i$  and  $K2_i$  may be markedly wrong over some, or even all, of the element's operating range. The present invention suggests a relatively simple and easily applied but nevertheless effective solution to this difficulty, by dividing the operating range of the element into a plurality of adjacent regions, calculating the gain and offset correction factors for each region separately (upon the basis that the input/output relationship in that region is linear), and then in operation correcting the element's output in accordance to which region it is in.

In one aspect, therefore, this invention provides a method of determining the individual gain and offset correction factors for subsequent application, in a normalisation process, to the output values of each

element of an array of electromagnetic radiation detector elements used in an imaging system to provide an image of a viewed scene, in which method:-

the expected operating value range of the detector elements is notionally divided into a plurality of adjacent regions; and

5 for each region the individual correction values for each element are calculated upon the basis that the relationship between the element's input and output is linear thereover;  
whereby in operation each element's output value may be corrected using the correction factors appropriate both to that element and that region of the range into which its output value falls.

In another aspect, the invention provides a method of processing the output of an electromagnetic 10 radiation detector element array to improve the quality of the image generated therefrom, in which method prior to its use to generate the image the output of each detector element is first normalised by applying thereto the gain and offset correction factors appropriate both to that element and to that region of the range into which its output value falls.

The invention relates to normalising the output values of the detector elements in an array of elements. 15  
15 The nature of the detector element array may be any used or suggested for use in the Art for the relevant radiation (which may itself be visible or non-visible - UV or IR, say - light). Typical such arrays are hybrid structures of photovoltaic arrays on either a silicon CCD structure or an array of MOS switches, and specific examples of this type of array are the Integrated Photomatrix Ltd. IPL 2D1 (a 64 x 64 photodiode array sensitive to visible light) and the 32 x 32 M4680 IR CCD element array produced from Mullard.

20 In accordance with the invention the expected operating output value range for the detector elements is divided into a plurality of regions. While naturally the *whole* output value range could be so divided there seems little point in having regions within the range that are in practice never going to be used. Thus, the regions are within the expected operating value range - though, of course, what this range depends upon the elements themselves and the normal operating conditions! If by chance an output value falls in that part 25 of the range either above the highest region or below the lowest region (i.e., beyond either end of the expected operating range) then it can be arranged that it is treated, and thus corrected, as though it fell within the relevant highest or lowest region.

The expected output value range is notionally divided into regions - that is, the divisions are imaginary rather than actual, and occur merely at some arbitrary but predetermined values recognised (as explained 30 hereinafter) by the associated electronics. As also explained hereinafter, each region is bounded by a range point for which actual output values have been obtained.

The division of the output value range is into a plurality of regions. The number, size and position of these regions are interrelated, and to a degree dependent upon the expected actual shape of the curve defining the input/output relationship. As regards the number, "plurality" has its usual meaning of "two or more", and 35 with fairly linear input/output curves two may be sufficient (in which case the operating range is divided simply into a bottom half and a top half). Usually, however, it is advantageous to have more than two regions, and five regions (four points of division) seem generally quite sufficient.

As regards the size of the regions, while it would of course be possible to have them of different extents over the range, perhaps with the size smaller over those parts of the range that are most non-linear. 40

40 nevertheless it seems in practice quite satisfactory to have the regions much the same size.

So far as concerns the position of the regions, while again they might be spread unevenly across the operating range, nevertheless a generally even distribution seems quite acceptable.

Just as in the invention of the aforementioned Application No. 8329470 the gain and offset correction factors based upon an assumption of a linear input/output range are computed by first determining the 45 actual output when the array is directed at two uniform energy sources spaced in the radiation spectrum, so the regions may be defined, and the respective gain and offset correction factors computed, by directing the array at an appropriate number of uniform energy sources spaced over the expected scene spectrum (from hot via warm to cold, say). Two regions require three spaced sources, three require four, and so on ( $n$  requires  $n+1$ ). Naturally, the sources are so chosen as to provide the regions desired!

50 Having, as a preliminary matter, obtained and stored the two correction factors for each of the range regions for each detector element in the array, these are in operation employed to modify the value of each element's output before that output is used to construct the desired image. The principle of this is quite straightforward: as each element is "read" to determine its output so the position in the range of that output is found and there are retrieved from store the two correction factors applicable to that region for that 55 element. These are then applied to the output value, and the corrected - normalised - output value is passed on towards the image-forming apparatus. In practice it is scarcely more complicated. A particular set of equipment for performing the sequence is discussed in more detail hereinafter, but basically is as follows:

using a clock system to ensure synchronisation, an address generator provides an output which identifies both the next array element to be read and the locations in the stores - one for each region - that hold the 60 series of two correction values particular to that element; the element's actual output is then assessed to find which region it falls in, and the appropriate pair of correction values identified; the actual output is then passed into conversion means where the two correction factors are applied one after the other after they have been read out from the right location in the chosen store; and the modified output, now in "normalised" form, is passed out of the conversion means and on to the image-forming apparatus.

65 The assessment of each element's output value to find which region it falls in is itself very simple. One

particularly acceptable method involves using a sequence of a corresponding plurality less one of comparators in which are permanently stored details of the output values defining the points where adjacent regions meet, and the actual output value is compared in all of these (either simultaneously or sequentially) and their outputs combined to indicate at which level - and thus in which region - the detector element's 5 output value falls. This type of level assessment is itself quite conventional, and needs no further discussion here (though an example is described hereinafter with reference to the accompanying drawings).

Apart from the feature of having a plurality of regions in the element's output value range, each region having its own gain and offset correction factors, the invention is much the same as that of the aforementioned Application No. 8329470.

10 Accordingly:-

The method of the invention - and specifically the normalisation calculations and the storage of the constants involved - is conveniently performed under the control of a microprocessor - for example, a Zilog 280.

The image-forming apparatus will normally be a visual display unit (VDU) of the cathode ray tube 15 (television) type, which is "written" to frame by frame and field by field to produce the desired visible image, and the modified detector element array output is most preferably fed to the VDU via one or other of two temporary stores capable of holding the output values for one whole field at a time, with "dead" element correction.

The invention has so far been described in terms of a method. In another aspect the invention provides 20 apparatus for processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, which apparatus comprises means to normalise the output of each detector element prior to that output's use to generate the desired image, this normalising means being means for applying to each detector's output a gain correction factor and an offset correction factor each relevant to that particular detector, wherein: the factor-applying means itself includes (1) a plurality of stores 25 25 wherein are stored the gain and offset correction factors, for each detector element, for a like plurality of regions into which the detector element's expected operating output value range is notionally divided, and (2) assessment means whereby each element's output value may be assessed and the appropriate correction factors for that value of the element identified. In practice, of course, the factor-applying means will also include a multiplier and adder (to which are applied the output value to be corrected and, 30 respectively, the appropriate gain correction factor and the appropriate offset correction factor), an address generator (to identify the next element whose output is to be modified, and to identify the relevant set of correction factors) and a system driver (a clock). In its more preferred forms the apparatus also includes two video stores (for holding two sequential sets of modified detector arrayoutputs) and means to switch the input to those stores, and the output therefrom to an image generator, from one to the other, and very 35 preferably there is further incorporated means to provide for any faulty element an average output value based upon the output values for its neighbouring elements.

The invention extends, of course, to any imaging system, especially a thermal system, making use of the image-improving method or apparatus as described and claimed herein.

An embodiment of the invention is now described, though by way of illustration only, with reference to the 40 accompanying drawings in which:-

*Figure 1* is a schematic view of a thermal imaging system employing the method and apparatus of the invention;

*Figures 2A and B* are representational input/output plots showing various typical curves for detector element output values, and how these can be divided into regions;

45 *Figure 3* is a simplified block diagram showing the method and apparatus of the invention;

*Figure 4* is a more detailed block diagram of part of Figure 3; and

*Figure 5* is a more detailed version of all of Figure 3.

In Figure 1 there is shown a thermal imaging camera (11) viewing a scene (12) and providing a visible image of that scene in a television-type Visual Display Unit (13) via a processing module (14). The camera 11 employs an IR detector element array (not shown separately), and the processing module 14 normalises the output of that array in accordance with the invention to enable a meaningful image to be formed on the VDU 50 50 13. The nature of the processing module 14 is shown in more detail in Figure 3.

The input/output plots of Figures 2A and B show two possible curves (121A,B) describing the operating range of two different elements, and how each can be treated either as a segment of a single straight line or 55 as a combination of segments of two or more straight lines. Taking Figure 2A first, the plot is the continuous heavy line 121A. On a very simplistic view this can be thought of as approximating to the straight line segment (the dashed line 122A) between two points (123A, 124A) near each end, but this is clearly a rather inaccurate approximation, and a much better one is to consider the curve as two straight line segments (the dotted lines 125A, 126A) between the two points 123A and 124A and a third point (127A) mid-way between them, these three points dividing the curve into two adjacent regions.

60 Obviously, the more the number of points between the two other points 123A and 124A the closer each line joining consecutive point pairs is to the curve itself.

The "S" shaped curve 121B in Figure 2B is a more complex curve than 121A in Figure 2A, and needs more points, defining more regions, to ensure that the point-joining straight line segments give a good 65 approximation. As in Figure 2A, a rough approximation is a straight line segment (dashed line 131B) joining

two points (132B, 133B) near either end, but a better approximation is obtained by dividing the curve into three regions (defined by the two end points 132B and 133B) and two in-between points 134B and 135B) and thinking of it as the three straight line segments (the dotted lines 136B, 137B, 138B) joining consecutive pairs of these points.

5 It will be apparent from Figures 2A and B that the curve region into which output value falls is ascertained simply by comparing the value itself with some predetermined values noted when the points (as 127A, 134B) were defined. In Figure 2A, for example, the output value may be defined as belonging to the lower region if it is below the level associated with point OV 127A on the Output axis (and belonging to the upper region if above that level).

10 Figure 3 shows in more detail the processing module of Figure 1. The camera 11 contains an IR detector element array (21 in Figure 3, shown as a  $32 \times 32$  matrix of elements) that is driven, by clock pulses originating in the system Master Clock (22), to output its contents element by element to a Gain and Offset Corrector (23) within the Processing Module 14. As each output value is obtained it is assessed (27) to determine into which of four regions of the output curve it falls, and an appropriate signal is forwarded to a

15 multiplex Conversion Factor Store (25) to select which part of that store (*a*, *b*, *c*, or *d*) is relevant to that region. At the same time, and in synchronism, the Master Clock 22 causes an Address Generator (24) to provide the identifying address of the array element presently giving its output, and this address is also sent to the Conversion Factor Store 25, causing it to output from the selected part to the Gain and Offset Corrector 23 values for the Gain Correction Factor and Offset Correction Factor applicable to this region of this

20 particular element. The Corrector then normalises the element output (modifying it in accordance with first one and then the other Correction Factor), and outputs the resulting normalised value to the Video Store (26) where it is placed in the correct location for the relevant element as determined by that element's Address (which is also fed to the Video Store from the Address Generator 24).

In due time the contents of the Video Store are read out and passed to a VDU for display.

25 The Assessor 27 is shown in more detail in Figure 4, together with its outputs to the rest of the system. In this embodiment the detector element output is divided into four discrete regions, and references are taken of five uniform scenes defining each of these regions, the correction factors being stored in four Reference Stores. In order that the right set of Correction Factors is used, the detector element output is fed to the +ve input of an Operational Amplifier (201). Simultaneously, the address of the element is applied to RAM blocks 30 1, 2, 3 and 4 (which have previously been filled by the processor in Figure 5 - see below) in which are held the values of each element at the minimum level of illumination and the three transition levels. The outputs of the RAM are summed (205) to produce a 10 bit number which when applied to a 10 bit D/A converter (202) produces an analogue signal which is subtracted from the detector signal in the Operational Amplifier 201. A high speed Comparator (203) checks that the output is positive going, and if not allows the RAM block selector (204) to disable the most significant block of RAM which is presently enabled. Thus the output of D/A 35 Comparator 202 falls, and the output of Operational Amplifier 201 rises - and the Comparator 203 repeats the process until the RAM block has disabled sufficient RAM to cause a +ve output from the Operational Amplifier whereupon the block selector 204 then holds the number of the region in which the original signal fell - and thus the 2 bit number of the Reference Store (25a, *b*, *c* or *d* in Figure 3) to be used for normalisation 40 of the signal.

After processing, the 2 bits from the front end are added as Most Significant Bits (MSBs) to the result, producing a 10 bit result.

Figure 5 represents an even more detailed block diagram of the Processing Module 14 in Figure 1.

The hardware shown operates as follows.

45 The Master Clock 14 drives the Input Address Generator 24, which clocks the elements from the Array 21 (the +x and +y factors are chosen conveniently to produce CIR standard frequency for video, and also a suitable array driving frequency), hence each element is assigned a specific address. After passing through the Assessor 27, the analogue data is converted into digital form in an 8-bit A/D stage (31), and the Address Bus goes through a suitable delay (32) to keep in step with it. The Reference Store selection item determines 50 which of the Stores 33 - *a*, *b*, *c* or *d* - the Address Bus is to access to obtain the two conversion factors K1 (mantissa and exponent) and K2, while the data goes to sequential multiply (34a,b) and addition (35) routines. As K1 and the data are both 8 bit numbers it is possible to obtain a 16 bit number in the result; all that is necessary for this operation to work correctly is that K1 be stored in the form  $A \times 2^{-B}$ , where B is as small a number as 55 possible to allow the greatest resolution in A (thus,  $128 \times 2^{-6}$  is preferred to  $1 \times 2^{-9}$  as the next highest number storeable in either system is  $129 \times 2$  and  $2 \times 2^9$  respectively; obviously the former allows greater accuracy).

This exponent system of multiplication is chosen in preference to a standard 8 bit multiply. In the latter case, since the system is a normalisation procedure, the mean number stored as K1 is 1, and to obtain equal 60 sensing about the mean this must be defined as a middle bit of the 8 bit number (i.e., 00010000), which in in turn means that between levels of K1 the minimum change is 1 bit (i.e., 1/16th of the mean). This is equivalent to only 4 bit resolution, and is easily visible on a video picture. Also, this limits the maximum correction of gain to be  $\times 16$  or  $\times 1/16$  about the mean, which may be adequate for a staring array, but if a reasonable number of elements fall at the extremes of the correction then quantisation effects are 65 overwhelming, e.g. an element requires to be multiplied by 1/16 to normalise its response, and its nearest

- neighbour is slightly lower in response, requiring a higher normalisation correction. The next highest number possible is 2/16 which may well be 50% too large.
- The exponent type of multiply allows full 8 bit resolution to be maintained at  $\times 16$  and  $\times 1/16$ , and only suffers from quantisation errors on the same scale at multiples of  $\times 256$  or  $\times 1/256$  if K1 is stored as 8 bits 5 and K1 exponent stored as 3 bits.
- In this way, the gain of the system is normalised, and the data then proceeds down the 'pipeline' to an 8 bit addition/subtraction (35) to normalise offsets. As this is addition, and is linear (whereas multiplication is geometric), no special techniques are required, and K2 is stored in standard 2's complement form 8 bits deep. During this processing the address of the element undergoes a further delay to ensure that processed 10 data and address arrive at the Field Stores (36a,b) at the correct time. The data is stored in whichever of these Stores is in 'write' mode, determined by the Output Address Generator (37). Whichever Store is in write mode, the other is in read mode, sending data accessed by the Output Address Generator to the D/A converter (38) and finally to a Video Sync. Mixer (39) and output. The Output Address Generator 37 changes 15 the modes of the Field Stores (36a,b) after each field is read out. It also starts the Input Address Generator 24 at the same time thus ensuring that on power-up everything is synchronised to give data from the array downstream at the start of every field.
- With small Arrays - thus, 32 x 32 or 64 x 64 elements - the data comes downstream in less than 1 field, and so some time is left at the end of data load to the Field Stores for a Microprocessor (40) to access it and make corrections for dead elements. This is done in the following manner. The Microprocessor accesses a Dead 20 20 Address Reference Store (41) and reads five addresses - that of the dead element and its four nearest neighbours. It then accesses whichever Field Store 36a,b is not being accessed by the Output Address Generator 37, and reads the data in the four neighbours, averages these (sums them and divides by four), and write the result over what was in the dead address. It then goes back to the Reference Store and reads the next five addresses, and so on, until either all the dead elements are corrected or the system returns to a 25 data download.
- The system is used in the following way.
- Initially the Microprocessor 40 writes to all the Reference Store 33 storage areas setting K1 to 1 and K2 to zero, RAM areas 1,2,3 and 4 (of Figure 4) to zero, and the RAM Block Selector 204 to enable all the RAM areas. At this stage the raw and processed data are identical. The Array 21 is then directed at a uniform cold 30 temperature (preferably as cold as the minimum likely to be observed in a scene), and the Microprocessor copies the resultant image into RAM area 1 (and so the major off-sets due to the background temperature of the scene are removed). The residual image at this temperature is then copied into the Temporary Reference area (42) in the Reference Store 33. The Array 21 is now directed at a warmer uniform scene, and the resultant image is copied first into a further Temporary Reference area and then into RAM area 2; using 35 these two stored scenes the values of K1 and K2 for the first area are computed and stored in Reference Store 33a. When this is complete, the Temporary Reference area 42 is now filled with the scene which resulted when RAM Area 2 was filled, the Array 21 directed at another uniform, yet warmer, scene, and the K1 and K2 values computed and stored in Reference Store 33b. This process of calibration is repeated until finally all the RAM areas in the Assessor are filled and all four sets of K1 and K2 are computed and stored. At this stage 40 the Microprocessor then removes the restriction imposed on the RAM Block Selector, and the system is returned to the user mode with the input signal being automatically set to use the correct K1 and K2 corresponding to the area in which the signal fell. The Temporary Reference areas now hold the values of A<sub>i</sub> and B, for the warmest region which can be used to correct for dead elements.
- With this set-up procedure complete, the Microprocessor asks the Operator for a threshold for dead 45 elements. This is a number which, if the response is lower, will then be called "dead". When the threshold value is input, the Microprocessor scans the A<sub>i</sub> values and notes the addresses of any element below the given threshold along with its four nearest neighbours in the Dead Address area 41 of the Reference Store. This done it will then proceed to interpolate for these elements every field.
- As the constants and dead addresses are all software generated in the Microprocessor they can be stored 50 in any suitable compatible medium for future use, should the calibration be impracticable.
- A major advantage of the system is that since it is a normalisation the majority of the offsets of all the elements can be removed at the analogue stage, allowing only a small offset and signal to be digitised, which in turn leads to less bits required and hence lower cost. The system is easily expandable to operate with larger arrays as the kernel processing is independent of sensor size.
- 55 The delay from sensor to video is at most one field, but this can be eliminated should either the sensor be driven at standard CCIR rates or should a non-TV format be required. In this case, the D/A would be connected after the kernel processing, and the Field Stores removed (except for the area for storage of reference scenes).

## CLAIMS

1. A method of determining the individual gain and offset correction factors for subsequent application, in a normalisation process, to the output values of each element of an array of electromagnetic radiation detector elements used in an imaging system to provide an image of a viewed scene, in which method:-  
 5 the expected operating value range of the detector elements is notionally divided into a plurality of adjacent regions; and  
 for each region the individual correction values for each element are calculated upon the basis that the relationship between the element's input and output is linear thereover;  
 10 whereby in operation each element's output value may be corrected using the correction factors appropriate both to that element and to that region of the range into which its output value falls.  
 2. A method as claimed in Claim 1, in which the detector element array is a CCD IR element array.  
 3. A method as claimed in either of the preceding Claims, in which the detector element operating value range is divided into from two to five regions.  
 15 4. A method as claimed in any of the preceding Claims, in which all the regions are much the same size.  
 5. A method as claimed in any of the preceding Claims, in which the regions are spread generally evenly across the operating range.  
 6. A correction factor determining method as claimed in any of the preceding Claims and substantially as described hereinbefore.  
 20 7. A method of processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, in which method the output of each detector element, prior to its use to generate the image, is first normalised by applying thereto the gain and offset correction factors appropriate both to that element and to that region of the range into which its output value falls.  
 8. A method as claimed in Claim 7, in which there are, as a preliminary matter, obtained and stored the correction factors for each of the range regions for each detector element in the array, these then being in operation employed to modify the value of each element's output before that output is used to construct the desired image.  
 25 9. A method as claimed in Claim 8, in which in operation each element is "read" to determine its output, the position in the range of that output is found, there are retrieved from store the correction factors applicable to that region for that element, and these are then applied to the output value, and the corrected - normalised - output value is passed on towards the image-forming apparatus.  
 30 10. A method as claimed in Claim 9, in which the assessment of each element's output value to find in which one of the plurality of regions it falls is effected by using a sequence of a corresponding plurality less than one of comparators in which are permanently stored details of the output values defining the points where adjacent regions meet, and the actual output value is compared in all of these, and their outputs are combined to indicate at which level - and thus in which region - the detector element's output value falls.  
 35 11. An output processing method as claimed in any of Claims 7 to 10 and substantially as described hereinbefore.  
 12. Apparatus for processing the output of an electromagnetic radiation detector element array to improve the quality of the image generated therefrom, which apparatus comprises means to normalise the output of each detector element prior to that output's use to generate the desired image, this normalising means being means for applying to each detector's output a gain correction factor and an offset correction factor each relevant to that particular detector, wherein: the factor-applying means itself includes (1) a plurality of stores wherein are stored the gain and offset correction factors, for each detector element, for a like plurality of regions into which the detector element's expected operating output value range is notionally divided, and (2) assessment means whereby each element's output value may be assessed and the appropriate correction factors for that value of the element identified.  
 40 13. Apparatus as claimed in Claim 12, wherein the factor-applying means also includes a multiplier and adder (to which are applied the output value to be corrected and, respectively, the appropriate gain correction factor and the appropriate offset correction factor), and an address generator (to identify the next element whose output is to be modified, and to identify the relevant set of correction factors).  
 45 14. Apparatus as claimed in Claim 13, which also includes two video stores (for holding two sequential sets of modified detector array outputs) and means to switch the input to those stores, and the output therefrom to an image generator, from one to the other.  
 50 15. Apparatus as claimed in Claim 14, wherein there is further incorporated means to provide for any faulty element an average output value based upon the output values for its neighbouring elements.  
 16. Apparatus as claimed in any of Claims 12 to 15 and substantially as described hereinbefore.  
 55 17. Any imaging system, especially a thermal system, making use of the image-improving method or apparatus as claimed in any of Claims 7 to 16.